Preoperative bone health assessment and optimization in spine surgery

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OBJECTIVE The purpose of this investigation was to characterize the bone health in preoperative spine surgery patients. This information will provide a framework to understand the needs and methods for providing bone health optimization in elective spine surgery patients.

METHODS A retrospective study of 104 patients undergoing bone health optimization was performed. Patients were selected based on risk factors identified by the surgeon and suspected compromised bone health. Evaluation included history and examination, laboratory investigations, and bone mineral density (BMD) at 3 sites (femoral neck, lumbar spine, and radius). Patients' bone status was classified using WHO criteria and expanded criteria recommended by the National Osteoporosis Foundation (NOF). The 10-year Fracture Risk Assessment Tool (FRAX) scores of the hip and major osteoporotic fracture (MOF) were calculated with and without femoral neck BMD, with spine BMD, and with the trabecular bone score (TBS). Antiresorptive and anabolic agents were provided in accordance with meeting NOF criteria for treatment of osteoporosis.

RESULTS The mean patient age was 69.0 years, and 81% of patients were female. The mean historical height loss was 5.6 cm, and 54% of patients had a history of fracture. Secondary osteoporosis due to chronic renal failure, inflammatory arthritis, diabetes, and steroid use was common (51%). The mean 25-hydroxy vitamin D was 42.4 ng/ml and was normal in 81% of patients, with only 4 patients being deficient. The mean T-scores were -2.09 (SD 0.71) of the femoral neck, -0.54 (1.71) of the lumbar spine, and -1.65 (1.38) of the distal radius. These were significantly different. The 10-year FRAX MOF score was 20.7%, and that for hip fracture was 6.9% using the femoral neck BMD and was not significantly different without the use of BMD. The FRAX risk-adjusted score using the lumbar spine BMD and TBS was significantly lower than that for the hip. Osteoporosis was present in 32.1% according to WHO criteria compared with 81.6% according to NOF criteria. Antiresorptive medications were recommended in 31 patients and anabolic medications in 44 patients.

CONCLUSIONS Surgeons can reliably identify patients with poor bone health by using simple criteria, including historical height loss, history of fracture, comorbidities associated with osteoporosis, analysis of available imaging, and calculation of FRAX score without BMD. High-risk patients should have BMD testing and bone health assessment. In patients with osteoporosis, a comprehensive preoperative bone health assessment is recommended and, if warranted, pharmacological treatment should be started.

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KEYWORDS bone health optimization; spinal surgery; osteoporosis; FRAX; dual energy x-ray absorptiometry; fragility fracture

OPTIMIZATION of medical conditions before spine surgery is increasingly being performed to maximize outcomes, reduce the risk of adverse events, and improve efficiency. The most commonly targeted conditions, such as obesity, glucose control, and elimination of smoking, are optimized to prevent surgical site infections;

modifiable cardiovascular risk factors to reduce mortality; and, more recently, reduction of preoperative opioid consumption and resetting of patient expectations to improve overall pain management.¹⁻³ Additionally, teamwork, multidisciplinary care, and protocols are effective in improving care of complex spine patients.^{2,4}

ABBREVIATIONS BHO = bone health optimization; BMD = bone mineral density; DXA = dual-energy x-ray absorptiometry; FRAX = Fracture Risk Assessment Tool; HU = Hounsfield units; MOF = major osteoporotic fracture; NOF = National Osteoporosis Foundation; TBS = trabecular bone score; VFA = vertebral fracture assessment; 25(OH)D = 25-hydroxy vitamin D.

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Although spine surgery involves bone dissection, removal, fixation, or the biological process of fusion, bone health is rarely considered preoperatively, and available optimization strategies are not widely applied. Dipaola et al. surveyed 86 spine surgeons who reported that only 60% evaluated bone mineral density (BMD) after fragility fracture and 40% before a spine fusion, and 18% assessed for metabolic abnormalities.⁵ Kuprys et al. evaluated bone health assessment over time in spinal deformity surgery patients. They found that there was an increased discussion in office notes but no change in bone interventions.⁶

Osteoporosis is common in patients undergoing spine surgery and is often undiagnosed. Schmidt et al. evaluated 144 spine surgery candidates older than 50 years and found that 27% had osteoporosis, 37.5% had evidence of prior fracture (most were occult vertebral fractures), and 75% were vitamin D deficient.⁷ Bjerke et al. performed dual-energy x-ray absorptiometry (DXA) in 140 patients having lumbar fusion and found that 10% had osteoporosis and 58.6% had osteopenia.⁸ Thus, while low bone density is common preoperatively in spine surgery patients, the role of osteoporosis assessment in preoperative care remains unknown, as few studies have evaluated the systematic application of bone health assessment/optimization to elective surgery populations.

Bone health optimization (BHO) is a comprehensive program aimed at improving BMD, correcting modifiable factors related to bone health, and stimulating osteoblastic activity in the skeleton to condition the spine to optimize recovery after surgery.⁹ Several proposed guidelines for primary osteoporosis treatment and secondary fracture prevention can be adopted to identify patients who should have bone density measurement and laboratory testing and, when indicated, receive medical treatment before undergoing spinal surgery.^{10–12} We hypothesize that poor bone health is common in elective surgery patients and that many meet criteria for medical therapy. The purpose of this article was to characterize spine surgery patients who have been referred to the University of Wisconsin's BHO program. This study will provide a framework for understanding the complexity of evaluation and treatment protocols, how this care might be applied, and the severity of bone disease that is present in typical elective surgical patients.

Methods

Patient Cohort

This retrospective study included 104 spine surgery candidates who were referred to the University of Wisconsin BHO clinic from September 2017 to March 2019. Patients were referred by their surgeons as potentially having osteoporosis based on the presence of known risk factors, evaluation of opportunistic CT, use of medications known to cause bone loss, prior diagnosis of osteoporosis, and a history of prevalent fractures. The inclusion criteria were that patients were 50 years of age or older and had planned thoracolumbar surgery. This study was approved and exempt from obtaining signed informed consent by the University of Wisconsin IRB.

Bone Health Assessment

Bone health assessment was performed by a bone health specialist physician or physician assistant coordinator in our fracture liaison service. Patients underwent a comprehensive history, review of risk factors for osteoporosis, fracture history, and laboratory tests. At the time of surgery scheduling, patients were asked to consume 2000–5000 IU of vitamin D and 1200 mg/day of calcium. During bone health assessment, there was discussion of fall prevention, the potential to improve surgical outcomes in osteoporotic patients, and the need to modify risk factors, such as elimination of toxins. Antiosteoporosis medication was offered to patients only if they met criteria for osteoporosis. Our preference in this cohort was to offer anabolic medications. However, other considerations regarding whether medication was offered and which type was prescribed depended on comorbidities, past use of medications, costs, osteoporosis severity, and patient preferences.

As part of bone health assessment, DXA was performed, and 10-year Fracture Risk Assessment Tool (FRAX) scores of hip fracture and major osteoporotic fracture (MOF) were calculated with and without BMD. A FRAX score was considered high based on a 10-year MOF risk $\geq 20\%$ or a 10-year hip fracture risk $\geq 3\%$.^{11–13} In patients who underwent DXA at our facility, the FRAX score was adjusted using the trabecular bone score (TBS).^{13,14} TBS was classified as values < 1.23 indicating degraded bone, values between 1.23 and 1.31 indicating partially degraded bone, and values > 1.31 indicating intact bone.¹⁴ The FRAX score was also adjusted by substituting spine BMD for femoral neck BMD. Vertebral fracture assessment (VFA) was obtained in 48 patients and TBS in 73 patients. The VFA was positive only for moderate and severe fractures according to the criteria of Genant et al.¹⁵ Opportunistic CT scans to measure mean Hounsfield units (HU) at L1 were available for 32 patients.

Bone status was determined using the WHO criteria based on T-score: a T-score ≤ -2.5 indicates osteoporosis, a T-score of -1.0 to -2.4 indicates osteopenia, and a T-score > -1.0 indicates normal bone status.¹¹ In addition, the National Osteoporosis Foundation (NOF) and National Bone Health Alliance classifications were applied, thereby defining osteoporosis as any of the following: T-score ≤ -2.5 ; hip or spine fracture; and T-score ≤ -1.0 to -2.4 with a FRAX 10-year hip fracture risk $\geq 3\%$ or MOF risk $\geq 20\%$.¹¹

Statistical Analysis

Comparison between groups was performed with ANOVA and the Student t-test using Microsoft Excel (version 16.6). A significance level of $p < 0.05$ was chosen.

Results

One hundred four patients were referred for BHO, of whom 84 were females (Table 1). The mean patient age was 69.0 (SD 8.1) years. All patients were Caucasian except 2 reporting Asian ancestry. The mean BMI (kg/m^2) was 27.6 (SD 5.8) with 6 patients having a BMI < 20 and 12 having a BMI ≥ 35 . Seven patients were using tobacco, and 3 reported using ≥ 3 alcohol units per day.

TABLE 1. Demographics and risk factors for osteoporosis

	Value
Mean age in yrs (SD)	69.0 (8.1)
Female/male, n	84/20
Mean BMI in kg/m ² (SD)	27.6 (5.8)
Caucasian/Asian race, n	102/2
Tobacco use, n	7
Alcohol ≥ 3 U/day, n	3
Comorbidities, n	
Diabetes	15
Inflammatory arthritis	14
Chronic renal failure	8
Use of steroids, ≥ 5 mg/day	16
Historical height loss in cm (n = 83)	
Mean (SD)	5.6 (3.0)
<2, n (%)	11 (13.2)
2–4, n (%)	24 (28.9)
>4, n (%)	48 (57.8)
Parental hip fracture, n (%)	17 (16.3)
History of fracture, n (%)	56 (53.8)
History of spine fracture, n (%)	15 (14.4)
Mean 25(OH)D in ng/ml (SD)	42.4 (14.5)

Historical height loss was available in 83 patients. The mean height loss was 5.6 (SD 3.0) cm. Forty-eight patients (58%) had historical height loss ≥ 4 cm, which exceeds NOF recommendations for vertebral imaging.¹¹ Another 24 patients had a 2- to 4-cm height loss.

Fractures had occurred in 56 patients (53.8%); 26 had 1, 16 had 2, 9 had 3, and 5 patients had 4 or more prior fractures. Fifteen patients (14.4%) had prior spinal fractures. Seventeen patients reported a parent with a hip fracture.

The 25-hydroxy vitamin D [25(OH)D] level was measured in 101 patients at the time of BHO clinic consultation. At the time of surgical consultation, patients were advised to consume 2000–5000 IU, which was 2–4 weeks earlier. The mean 25(OH)D was 42.4 (SD 14.5) ng/ml. Overall, 82 patients (81.1%) were vitamin D replete (≥ 30 ng/ml), 15 had insufficient levels (20–30 ng/ml), and only 4 had deficient levels (≤ 20 ng/ml). Hyperparathyroidism was present in 4 patients.

Medical comorbidities that affect bone metabolism

FIG. 1. DXA T-scores of the femoral neck, lumbar spine (L1–4), and one-third distal radius.

were common, including stage 3 or worse chronic renal disease in 8 patients, diabetes in 15 patients, and inflammatory arthritis in 14 patients. In addition, 16 patients were using ≥ 5 mg/day of glucocorticoid medication. Overall, 51% of patients had secondary osteoporosis.

DXA was performed in 103 patients (Table 2). The mean hip T-score was -2.09 (SD 0.71) in 99 patients, that for the lumbar spine (L1–4) was -0.54 (1.71) in 90 patients, and that for the distal one-third radius was -1.65 (1.38) in 81 patients (Fig. 1). The T-scores were significantly different between sites ($p < 0.05$). The VFA showed 5 cases of occult fracture and was negative in 43 cases. The TBS indicated degraded microarchitecture in 24 patients, partially degraded microarchitecture in 19 patients, and intact in 30 patients (Table 3).

The 10-year FRAX hip and MOF scores were determined with and without BMD and were used to aid in treatment decisions per NOF guidelines (Table 4).¹¹ The mean FRAX hip fracture score was 6.9% (SD 5.7%) and the MOF score was 20.7% (8.9%). Overall, 80 patients had a $\geq 3\%$ risk of hip fracture, 52 patients had $\geq 20\%$ MOF risk, and 83 patients had either MOF risk $\geq 20\%$ or hip fracture risk $\geq 3\%$. The mean MOF FRAX score without BMD was 19.5% (9.8%), which was not significantly different from FRAX with BMD ($p > 0.05$).

The FRAX score adjusted with TBS resulted in a decreased risk of hip fracture (to 2.6%) and decreased risk of MOF (to 12.9%), which were significantly lower than when using hip BMD. Similarly, the spine BMD-adjusted

TABLE 2. DXA T-scores

	Femoral Neck	Lumbar Spine	1/3 Distal Radius	Lowest T-Score
No. of patients	99	90	81	103
T-score				
Mean (SD)	-2.09 (0.71)	-0.54 (1.71)	-1.65 (1.38)	-2.32 (0.88)
≤ -2.5	32	11	24	48
≤ -1.0 to -2.4	62	35	28	50
> -1.0	5	44	29	6

Values represent the number of patients unless stated otherwise.

TABLE 3. Results of VFA, TBS, and opportunistic CT

	Value
VFA	
No. of patients	48
Fractured	5
Not fractured	43
TBS	
No. of patients	73
Mean (SD)	1.28 (0.11)
Normal	30
Partially degraded	19
Degraded	24
Opportunistic CT	
No. of patients	32
Mean (SD) HU at L1	113.0 (44.8)
≤110 HU	18
≥150 HU	6

Values represent the number of patients unless stated otherwise.

FRAX score was significantly lower than when hip BMD was used ($p < 0.05$, Table 4).

Opportunistic CT scans that could measure L1 HU were available in 32 patients. The mean L1 HU was 113.0 (SD 44.8, range 29–260). Using a threshold of ≤ 110 HU to establish osteoporosis, 18 patients (56.3%) were likely to have and only 6 had what is considered normal bone (HU ≥ 150).

The bone status using WHO criteria was osteoporotic in 33 (32.1%), osteopenic in 61 (59.2%), and normal in 9 (8.7%) (Table 5). Using the NOF criteria resulted in classifying osteoporosis in 84 patients (81.6%).

Pharmaceutical medications were recommended in 75 patients (72%). Anabolic therapy was prescribed in 44 patients (42%) (abaloparatide or teriparatide), and antiresorptive therapy was prescribed in 31 (30%) (alendronate, risedronate, zoledronic acid, or denosumab) (Table 5).

Discussion

This study showed that in patients referred for BHO, decreased BMD and abnormal bone microarchitecture were common. The majority of patients (81.6%) met NOF criteria for osteoporosis treatment, and 73% of all pursued therapy. A history of one or more prior fractures was com-

TABLE 5. Bone classification and treatment

	Value
WHO	
Osteoporosis, T-score ≤ -2.5	32.1%
Low bone mass, T-score ≤ -1 to -2.4	59.2%
Normal, T-score > -1.0	8.7%
NOF recommendations	
Osteoporosis	81.6%
No osteoporosis	18.4%
Pharmaceutical treatment, n	
Anabolic	
Teriparatide	30
Abaloparatide	14
Antiresorptive	
Bisphosphonate	30
Denosumab	1

mon. We also found that the FRAX assessment, with or without femoral neck BMD, was useful in categorizing risk. The finding of a high prevalence of decreased bone health in a spine surgery patient population highlights the need for surgeons to consider bone health assessment before an elective surgical procedure.

Patients were referred by their spine surgeons for preoperative BHO based on history, physical examination, and review of radiographs. These factors are available to all spine surgeons. Identification of prior fractures is simple by history but also using imaging and performing VFA during DXA. The presence of a spine fragility fracture indicates that the patient has osteoporosis per NOF recommendations and would likely be at risk for osteoporosis-related complications (Fig. 2A).¹¹ Other risk factors such as inflammatory arthritis and the use of medication such as corticosteroids are associated with decreased bone strength and should prompt further investigation of bone health. Historical height change is easily overlooked and correlates strongly to the severity of bone disease in the general population.¹⁶ A recent 2-cm change in height or a historical change of 4 cm warrants spinal imaging per NOF guidelines.¹¹ In spine patients, height change may also represent progressive deformity that in itself may be associated with osteoporosis.¹⁷ In our opinion, a preoperative patient with a recent 2-cm change in height or historical 4-cm height loss should undergo DXA. Using

TABLE 4. FRAX score

	No. of Patients	10-Yr Hip Fracture Risk		10-Yr MOF Risk		No. of Patients Exceeding Criteria of $\geq 3\%$ Hip or $\geq 20\%$ MOF
		Mean % (SD)	No. of Patients w/ $\geq 3\%$	Mean % (SD)	No. of Patients w/ $\geq 20\%$	
w/ femoral neck BMD	99	6.9 (5.7)	80 (80.8%)	20.7 (8.9)	52 (52.5%)	82 (82.8%)
w/ BMD	104	6.8 (6.7)	69 (66.3%)	19.5 (9.8)	44 (42.3%)	72 (69.2%)
w/ lumbar spine BMD	72	2.4 (3.0)	21 (29.2%)	12.5 (7.8)	9 (12.5%)	23 (31.9%)
w/ TBS adjustment	72	2.6 (3.1)	21 (29.2%)	12.9 (7.5)	10 (13.9%)	21 (29.2%)

FIG. 2. **A:** A 78-year-old female patient presented with neurogenic claudication from increasing degenerative scoliosis and spondylolisthesis at L4–5 (arrow). A compression fracture is present at L2. She had a history of right hip fracture treated with an intramedullary nail 6 years earlier and was found to be “osteopenic” and was treated for 2 years with alendronate. Her BMI was 19.5, and she had lost 37 mm in height. **B:** A DXA scan showed a left total hip T-score of -2.4 . This was invalid due to osteoarthritis. **C:** The T-score of the lumbar spine (L1–4) was -2.6 but was also invalid due to degenerative changes at L4–5 and L2–3. The microarchitecture of the patient’s lumbar spine TBS was degraded. The one-third distal radius DXA T-score was -3.6 . **D:** VFA (left) showed old fractures at T8 and L2 (arrows). A sagittal chest CT scan (right) from 6 years earlier demonstrated the old fractures. The HU (ellipse) at L1 was 92. A diagnosis of osteoporosis was made, and teriparatide was administered. After discussion of the risk of surgery, the patient is attempting further nonoperative care. A DXA scan obtained 18 months after teriparatide showed a lumbar spine BMD increase by 8% (not shown).

all of these measures, more than 80% of these patients had osteoporosis and were candidates for pharmaceutical treatment.

Vitamin D is needed for calcium absorption from the gut, mineralization of osteoid matrix, and collagen cross-linking and is almost always universally deficient in spine surgery patients.^{18–21} Correction is rarely performed, and deficiency is related to poorer outcomes.^{18,20,22–24} Correction of vitamin D deficiency is simple and well within the skill set of all spine surgeons; asking patients to use 2000–5000 IU daily vitamin D3 at the time of surgery assessment is simple, inexpensive, and virtually side-effect free. With this approach, we were surprised that the vast majority of patients were vitamin D replete by the time of BHO.

Bone strength is related to BMD and bone quality. Bone quality is associated with mineralization, collagen organization, and bone microarchitecture. BMD is measured by DXA and can also be estimated by opportunistic CT.²⁵ DXA provides a reliable method to assess BMD but can have errors and misinterpretations (Fig. 2B and C).²⁶ To classify bone health, the lowest femoral neck T-score rather than that of the spine (especially in spine surgery candidates) or, alternatively, the lowest T-score from any site should be used.¹¹ The International Society for Clinical Densitometry recommends when assessing lumbar spine BMD that only spine segments without artifact or deformity should be used, assessment must include at least 2 segments, and no single segment should have greater than 1 standard deviation difference than any other.²⁷ This guideline was confirmed in the current study, as the femoral neck T-score was 1.5 standard deviations lower than that of the lumbar spine. This also translated into change of bone classification, where the FRAX 10-year MOF risk was 20.7% with femoral neck BMD and only 12.5% with spine BMD. Using spine BMD to estimate risk or classify

bone health in spine surgery patients will lead to underestimation of disease.

The diagnosis of osteoporosis, and thus indications for management, has undergone change from using the WHO classification based on BMD to including function such as presence of hip or spine fractures and predictions of fracture risk.^{11,12} The latter method has been advocated since T-scores ≤ -2.5 are present in less than half of the cases of hip and spine fragility fracture.^{11,12} This finding is consistent with our results because only one-third of our patients had osteoporosis by WHO criteria compared with more than 80% by NOF criteria. In our BHO program, the expanded criteria were used to determine who should have pharmaceutical treatment.

Advanced densitometry, including VFA, TBS, and opportunistic CT, were utilized. VFA provides a lateral image from T3 to L5 that is used to identify prevalent spinal fractures (Fig. 2D). Depending on the population studied, spinal fractures can be seen in 30% of patients, many of which are occult.¹¹ Prevalent fractures are important in patients being considered for spine surgery, although in this study the percentage was relatively low, given the high percentage of patients with osteoporosis. The TBS measures textural variations using variation of the gray level on lumbar DXA.¹⁴ It is an index of bone microarchitecture and correlates to the number and connectivity of trabeculae. The TBS was abnormal in almost two-thirds of our patients, although it did not affect the FRAX score. Since TBS relates to bone microarchitecture, it is a better predictor of fracture than BMD, and therefore it might help to assess how screws and interbody devices are likely to perform.^{28,29} TBS has been shown to be useful, even in the presence of degenerative changes in the lumbar spine, although—in this study—TBS tracked with spine BMD better than hip BMD.³⁰ Opportunistic CT is easy to perform

using existing CT data obtained for any purpose.²⁵ An L1 HU ≤ 110 indicates a high likelihood of osteoporosis, while one of ≥ 150 indicates normal bone.^{25,31} HU values < 100 have been associated with cage subsidence, pedicle screw loosening, and proximal junctional kyphosis and fracture.^{32–34} Low HU indicating an osteoporotic condition may also predict poorer union after fusion.³⁵

The optimal timing and which medication should be used for preoperative optimization is unknown. There is evidence that both antiresorptive agents (oral and parenteral forms of bisphosphonates and denosumab) result in better outcomes and fewer complications than placebo.^{36–38} Similarly, teriparatide, an anabolic agent, has been shown to speed fusion and reduce hardware complications in spine surgery.^{36,39–41} We prefer anabolic medications, but these were only used in half of our cases. Surgeons are concerned that antiresorptive agents will impair spinal fusion. However, adverse effects of antiresorptive medications on spinal fusion have not been reported, and, in fact, multiple studies have shown equal or better results.^{42–45} Surgical delay was not reported in the current study because many patients were not given surgical dates until after bone health assessment and initiation of treatment was concluded. In general, our approach for any osteoporotic patient was to administer at least 3 months of pharmaceutical treatment before surgery, if possible. In 5 cases, surgery was not performed largely due to severity of bone disease.

Other limitations of this study were that it was not designed to determine the efficacy of preoperative BHO. We do not know if our treatment resulted in better outcomes and lower complications. Further research is clearly needed. Our patients were surgeon selected and therefore other patients with osteoporosis may have been missed. The recently published International Society for Clinical Densitometry position statement to identify who should undergo DXA before surgery was not available at the time of this study but, hopefully, it will aid in the identification of at-risk patients who may benefit from screening and preoperative BHO.¹⁰ Our population was from a tertiary referral academic center, and the majority of patients were older Caucasian adults. Since osteoporosis has a racial, age, and sex influence, results may not apply to all populations.

Conclusions

Preoperatively, surgeons are able to identify patients with potential poor bone health using easily applied criteria. DXA should be interpreted using femoral neck or total hip BMD and not the spine T-score in the presence of deformity or degeneration, and the FRAX score should be calculated. If available, newer technologies, including VFA and TBS, can aid in estimation of bone health. Four to 5 weeks of 2000–5000 IU daily vitamin D3 supplementation started at the time of surgery scheduling will result in the majority of patients being replete. Referral to a bone health specialist or fracture liaison-type service is suggested for patients 50 years of age or older with suspected poor bone health for comprehensive care, including correction of modifiable risk factors and pharmaceutical treatment.

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Author Contributions

Conception and design: Anderson, Binkley. Acquisition of data: all authors. Analysis and interpretation of data: Anderson, Kadri, Binkley. Drafting the article: Anderson, Binkley. Critically revising the article: all authors. Reviewed submitted version of manuscript: Anderson, Binkley. Approved the final version of the manuscript on behalf of all authors: Anderson. Statistical analysis: Anderson, Kadri. Administrative/technical/material support: Anderson, Hare, Binkley. Study supervision: Anderson, Binkley.

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